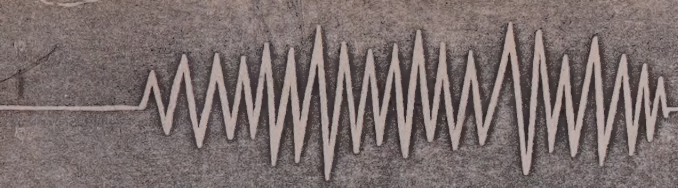



TR-888

TSC-810

TSC-801

Quick-rental® instruments
GENERAL ELECTRIC CO.
11223 S. HINDRY AVENUE
LOS ANGELES, CA 90045
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# operations and service manual

MASTER

GENERAL ELECTRIC
INSTRUMENTATION & COMMUNICATION
1200 KONA DRIVE
COMPTON, CA 90220
(213) 642-5317

Electronic Services - Los Angeles
M14542X

techni-rite
ELECTRONICS
INCORPORATED
TECHNI-RITE INDUSTRIAL PARK - WARWICK, R. I.

MASTER

GENERAL ELECTRIC
1200 NORTA DRIVE
COMPTON, CA 90220
(213) 542-8317

## A. FUNCTIONAL DESCRIPTION:

The TR-888 is a compact, portable, eight channel direct-writing analog recorder. It writes by means of heat and pressure-sensitive chart paper.

Techni-Rite chart paper is relatively resistant to marking through abrasion in handling, and the recorded chart can be safely stored at temperatures up to 140° F.

The open-frame, mother-plate mechanical design concept of the TR-888 makes component replacement and repair relatively straightforward.

Each of the Eight Analog recording channels can be "programmed" to record a wide range of input signals, including D.C. signals, A.C. signals up to 125Hz, and stress-strain information from resistive-type strain gages. No internal electrical realignment is necessary when changing from one type of signal conditioner to another. Each TR-888 Recorder is supplied with eight plug-in signal conditioners (of the customer's choice) when installed.

The limiting factor of this Recorder, as with all recorders, is its Rise Time. The Rise Time specification of a Recorder directly defines its ability to record signals which exhibit a relatively large change in amplitude over a short period of time. The Rise Time (the time required by the stylus to move from 10% to 90% of the distance between chart center and either chart margin) is in the range of 4 to 5 milliseconds.

The TR-888 is a "Fourth Generation" machine. Its design embodies the absolute minimum number of components required to properly fulfull its function. As such, the reliability of the TR-888 as a recording system is extremely high. Please

read carefully and perform the simple Preventive Maintenance instructions and procedures listed in Chapter V of this Manual in order to maintain the reliability of the Recording System at this high level.

B. SYSTEM BREAKDOWN

1. BASIC RECORDER CHASSIS: The components listed below comprise the Basic Recorder Chassis:

Chart Transport Mechanism
Chart Mandrel Assembly
Dual-Speed Chart Drive Motor
Four-Speed Constant Mesh Chart Speed Transmission
Heavy Duty Stylus Heat Transformer
Power Transformer for each Analog Channel (8)
Integrated Amplifier Pen Motor for each Analog Channel (8)
Control Circuitry

2. Each recorder is, in addition, equipped with eight signal conditioners which are fully defined in Chapter IV. Briefly, however, the breakdown of a typical signal conditioner is as follows:

Control Panel and Circuitry
Power Supply
Calibration Circuitry
Signal Conditioning and Amplification stages.

C. LIST OF EQUIPMENT AND ACCESSORIES SUPPLIED

The recording system should arrive in a single shipment of two cartons: The larger carton, weighing approximately 75 lbs. will contain the Recorder and line cord with Signal Conditioners installed. The smaller carton, weighing approximately 12 lbs., will contain the following:

1 each Chart Mandrel Assembly

1 set of nine mating input connectors (8 for Analog Inputs, 1 for Event Input)

1 each Accessory Maintenance Tool Kit containing the following:

1 each Stylus Installation Tool

1 each Pen Motor Damping Alignment Tool

The following extra-cost accessories, if ordered, will be shipped in separate cartons:

Special Starter Kit, including supply of Chart Paper and spare Stylus

Rack Mounting Adaptor Kit

Chart Rewinder

Accessories supplied on special order will be listed on the packing list which will accompany all shipments.

D. LIST OF TEST AND ALIGNMENT EQUIPMENT REQUIRED BUT NOT SUPPLIED

The following Test Equipment is recommended for proper long-term maintenance and calibration of the TR-888 Recorder:

1. Signal Generator

   Hewlett Packard
   Model 202A
   Wave-Tek
   Model 110, or equivalent

2. Precision Voltage Source

   Monroe
   Model 205, or equivalent
   (Monroe Electronic Laboratories, Middleport, N.Y.)

3. Precision D.C. Volt Meter

   Fluke
   Model 801H
   (John Fluke Co., Seattle, Washington)

   Alternately a good quality digital Volt Meter capable of 0.1% measurement accuracy may be employed

4. Stylus Gage

   Techni-Rite Model TAC-129

5. Signal Conditioner Extender Card/cable
   Techni-Rite Model TAC-130

## E. SYSTEM SPECIFICATIONS - BASIC RECORDER

| | |
|---|---|
| NUMBER OF CHANNELS | eight analog |
| EVENT MARKERS | right hand standard; left hand optional |
| FREQUENCY RESPONSE | D.C. to 125 Hz ± 3 db; 8 mm p-p. |
| RISE TIME | 4 to 5 ms; 1% overshoot |
| CHART SPEEDS | Eight: .5, 1, 2.5, 5, 10, 20, 50, 100, mm/sec., ± 1% |
| CONTROLS | Power, Chart Speeds, Stylus Heat |
| CHART PAPER | Eight 40 mm wide channels, each ruled with 50 lines; 200' long. |
| STABILITY | 0.5 div/10° C to 40° C |
| DIMENSIONS | 17½" W x 19" H x 6" D |
| WEIGHT | 65 lbs. |
| POWER REQUIREMENTS | 115 VAC/60 Hz, 400 W max. |
| ELECTRONICS | Recorder accepts any "mix" of Plug-in Signal Conditioner listed below. |
| LINEARITY | ± 1% |

RECORDER SPECIFICATIONS WITH SIGNAL CONDITIONERS

| | MEDIUM GAIN MODEL TSC-810 | HIGH GAIN MODEL TSC-801 | STRAIN TRANSDUCER MODEL TSC-5 |
|---|---|---|---|
| SENSITIVITY | 10 mv/div | 1 mv/div | 5 uv from transducer produces one div deflection on chart |
| ATTENUATOR POSITIONS | 10,20,50,100, 200,500 mv/div; 1,2,& 5v/div | 1,2,10,20,100, 200 mv/div 1, 2, v/div | x1, x2, x5, x10, x20, x50, x100 |
| INPUT IMPEDANCE | 500 K, single ended | 500 K,balanced | 10 K ohms |
| CONTROLS | Position, Gain, Attenuator | Position, Gain Attenuator, Zero Suppress. | Gain, R.& C.Balance Operate-Balance, Cal,Range,Position |
| SIGNAL INPUT | Rear mating connector provided | Rear mating connector provided | Rear mating connector provided |
| ZERO SUPPRESSION | None | 10 X full scale at any attenuator setting | N/A |
| TRANSDUCER | N/A | N/A | 100 ohms min. at input |
| EXCITATION VOLTAGE | N/A | N/A | 4 to 6 VAC RMS 2000 Hz |
| CALIBRATION | Internal | Internal | Internal |

## A. INSTALLATION

The TR-888 Recorder is a Portable device which may be mounted in a Rack by means of a Rack-Mounting Adaptor which is available as an extra cost accessory. Full information and instructions for this signal conversion are included with the Rack-Mounting Adaptor Kit.

In its Portable configuration, the Recorder will operate with its writing table in the vertical or the horizontal plain, that is, with the Recorder standing upright or lying flat.

> CAUTION: Please allow at least 2 inches clearance between the recorder side plates and adjacent equipments, especially in the areas which have been punched with elongated slots, for proper air passage.

The TR-888 may also be hung on a wall by means of heavy-duty screw eyes or hooks which are capable of supporting the 65 lb. weight of the Recorder. In this configuration, the Recorder may be supported by its carrying handle, one hook at each end.

Please note that the TR-888 should not be permanently fastened to a wall, as access to the rear of the Recorder is required in order to replace fuses and perform maintenance functions.

## B. INSTRUCTIONS FOR WIRING INPUT CONNECTORS

Use only shielded cable when making up cables to connect the signal to the TR-888. In the case of the TSC-5 Strain Gage Signal Conditioner, please note that a double-shielded or two separately shielded cables are required, whereas the TSC-50, the TSC-810, and the TSC-801 Signal Conditioners require at most a double-conductor shielded cable. The shielded cable

should be of good quality, such as produced by Belden, their Number 8451-1000. You may refer to the signal conditioner schematics at the rear of this manual, or to the table below to determine the appropriate connector pin numbers.

1. INPUT CONNECTOR WIRING TABLE
(Numbers refer to Input Connector Pins)

| Signal Conditioner Model Number | Non-Inverting Input | Common | Inverting Input |
|---|---|---|---|
| TSC-810 | 1 | 3 | N/A |
| TSC-50 | 1 | 3 | N/A |
| TSC-801 | 1 | 3 | 2 |
| TSC-5 | --- See TSC-5 Manual --- | | |

2. Event Markers:
Install a normally open switch or push-button of 500 Ma. contact rating between the connector pins listed below: Close switch to actuate Event Marker

| | |
|---|---|
| Right-Hand Marker | Pin 3 and Pin 5 |
| Left-Hand Marker | Pin 1 and Pin 4 |

C. PREPARE THE END OF THE SHIELDED SIGNAL CABLE AS FOLLOWS:

1. Remove a 1¼" length of the outside plastic sheathing.
2. Remove a ¾" length of the metal shielding layer.
3. Strip off 3/16" insulation from each of the inner conductors which are to be used. Twist and tin with solder each of the inner conductors. Form each inner conductor into a hook.

Prepare the input connector as follows:
1. Disassemble molded insert from outside metal shell by unscrewing the single clamping screw.
2. Slide the metal shell and rubber strain relief assembly onto the prepared signal cable.

3. Note that the connector pin numbers are molded onto the inside end of the insert; insert each signal wire into the appropriate solder connector of the insert. Crimp each signal wire and solder.
4. Note the U-shaped shield clamp; lay the exposed portion of the shield into the clamp, allowing a slight amount of extra signal lead length between the soldered signal wire connections and the shield clamp.
5. Using a pair of long-nosed pliers, carefully bend the ends of the shield clamp over the cable shielding, then firmly clamp the cable shield into place using slight additional pressure from the jaws of the pliers.
6. If extended operation in corrosive atmospheres is contemplated the cable shield may be soldered to the shield clamp if care is taken to avoid melting and shorting together of the inner conductors due to excessive heat.
7. Carefully inspect the entire assembly to verify that no wires are shorting together, then slide the metal shell down over the inserts and reinstall damping screw.

## D. CONNECTING RECORDER TO POWER MAINS

Power mains connection is made to the recorder through a detachable power cord. This power cord is supplied with the recorder complete with three-wire grounding plug when the recorder is designed to operate on 105-125 volts a.c., 60 hertz power. The detachable power cord is supplied less power plug, (which must be supplied by the customer) in the case when the recorder is supplied to operate on any other line voltage and frequency. In this case, the end of the line cord is stripped and the wire ends are tinned.

When such a recorder is supplied, connect the power cord wires as follows:

| Wire Color | Connect to |
|---|---|
| Black | A. C. Hot |
| White | A. C. Neutral |
| Green | Earth Ground |

## OPERATING INSTRUCTIONS

### A. CONTROLS AND INDICATORS

(Recorder Frame) There are three basic types of controls on the Recorder Frame, as follows:

| CONTROL NAME | CONTROL FUNCTION AND SENSE OF OPERATION |
|---|---|
| CHART SPEEDS | Rotary switch; select speed (MM/SEC) at which chart passes over the writing edge. OFF position, when selected, allows for Recorder warm-up and some rough alignment procedures without using chart paper. Turn the CHART SPEEDS CONTROL to the desired position. |
| MAIN POWER | Push Button; push for ON; push for OFF. MAIN POWER Indicator Lamp will light to indicate that the Recorder is receiving power. |
| TRACE WIDTH | Rotary Potentiometer Control for vernier adjustment of stylus heat and therefore of Trace Width. Nine TRACE WIDTH CONTROLS supplied; One for each Analog Stylus (8), and one control for the Event Marker Trace Width. These controls are to be adjusted for best writing while the recorder is in operation recording an actual signal. Turn controls clock-wise to increase Trace Width. |

### B. LOADING CHART PAPER

1. Mount chart paper onto chart mandrel as follows:
   a) Take the chart mandrel in one hand, and with the other hand, slide off the removable chart flange. Place the removable flange at your left and the mandrel proper at your right.
   b) Hold the chart roll in the left hand and position it

in such a fashion that the chart is coming off the rear of the chart roll and that the printed side of the chart is visible.

c) Insert the chart mandrel shaft into the right-hand end of the chart core and slide the removable flange onto the protruding left-hand end of the chart mandrel shaft.

d) It is suggested that for the first several loadings of the chart, at least, the recorder be placed in the vertical position. Note the two bat-shaped handles located at the upper left and upper right-hand extremities of the writing table; grasp both handles between the thumb and forefinger and pull straight out. This will disengage the writing table from its two snap-type locks. The writing table may now be swung out and down to a horizontal position.

e) Note the left and right-hand chart mandrel mounts located at each end of the Chart Magazine thus exposed; slide both locking bars firmly upward to the limit of its travel.

f) Insert the loaded chart mandrel straight into its mounts, and firmly slide each locking bar down into place.

g) Unroll 1 1/2 to 2 feet of chart from the chart roll, bring it over the writing edge, and while holding the end of the chart in one hand, carefully close the writing table, making sure that it has snapped into place.

h) Turn on MAIN POWER and set CHART SPEEDS switch to 5mm/sec. Tear the end of the chart paper into a VEE shape and slowly feed approximately 3" into the chart loading slot. The mechanism should then couple to the end of the chart and feed it automatically out through the exit slot.

i) Allow the chart to run through the recorder for distance of 3 to 5 feet, or until the chart has stabilized itself within the drive mechanism, and is flowing straight and free through the mechanism.

C. It is suggested at this point, unless the user has considerable experience with this type of recorder, that the short paper entitled, Sources of Error in Direct Writing Recorders be read. This paper is located at the rear of this manual. Its purpose is to outline in a direct fashion the various pitfalls in using a recorder of this type, and how to avoid them.

D. SIGNAL CONDITIONER CALIBRATION AND OPERATION

1. General Procedure

For all Signal Conditioner calibration procedures, set up Basic Recorder controls as follows:

a) Turn MAIN POWER, ON. Allow 15 minutes warmup.

b) Set CHART SPEEDS selector to 1 or 5 mm/sec.

c) Adjust TRACE WIDTH controls for a fine trace on all channels.

d) Refer to Specific Procedures below.

2. Specific Procedure, Model TSC-810

a) Turn round locking knobs on GAIN and POSITION controls counterclockwise 1/2 to 2/3 turn to unlock controls, then turn each locking knob clockwise until GAIN and POSITION controls are partially restrained from rotating.

b) Turn GAIN control fully counterclockwise.

c) Using POSITION control, set trace drawn by Recorder Stylus precisely to the center line of its channel (directly below the Signal Conditioner).

d) Turn GAIN control fully clockwise; if the Stylus moves from its center position by more than 2/5 of the smallest chart division, reset it to channel center line by means of the screwdriver adjustment Vo trimmer located behind its front panel access hole, marked "Vo".

e) Set Function Switch to CAL (calibrate) position. Set GAIN control to the position which causes the Stylus to

trace a line precisely 20 smallest chart divisions to the right of channel center. NOTE: 20 divisions are not equivalent to End Scale deflection, which is 25 divisions.

f) Return Function Switch to the OFF position and verify that the Stylus is tracing a line at exactly channel center; correct if necessary by means of the Position control.

g) Repeat steps e) and f) until Stylus traces precisely at channel center in OFF and at +20 chart divisions in the CAL position of the Function Switch.

h) The Signal may now be connected to the Signal Conditioner per Wiring Instructions given in Chapter II. The Position control and Function Switch may now be set at any position within their respective ranges of adjustment.

3. Specific Procedure, Model TSC-801

a) CAUTION

A MERCURY BATTERY IS USED IN THE "ZERO-SUPPRESS CIRCUITRY OF THIS SIGNAL CONDITIONER. THIS BATTERY HAS A SHELF LIFE OF 18 MONTHS AND A WORKING LIFE OF 3 to 6 MONTHS UNDER AVERAGE USE. WHEN THE TSC-801 SIGNAL CONDITIONER IS NOT IN USE, THE ZERO SUPPRESS SWITCH MUST BE IN THE OFF POSITION, OR THE BATTERY WILL BECOME USELESS AND WILL REQUIRE REPLACEMENT AFTER ONLY TWO OR THREE WEEKS.

b) Turn round locking knobs on GAIN and POSITION controls counterclockwise 1/2 to 2/3 turn to unlock controls, then turn each locking knob clockwise until GAIN and POSITION controls are partially restrained from rotating.

c) Turn GAIN control fully counterclockwise.

d) Using Position control, set trace drawn by Recorder Stylus precisely to the center line of its channel (directly below the Signal Conditioner).

e) Turn GAIN control fully clockwise; if the Stylus moves from its center position by more than 2/5 of the smallest chart division, reset it to channel center line by means of the (screwdriver adjustment) Vo trimmer located behind its front panel access hole, marked "Vo".

f) Set Function Switch to Io position; set screwdriver adjusted Io control through its identified front panel access hole for a "Null", the point at which the Recorded Trace most closely approaches the channel center.

g) Set Function Switch to CAL (Calibrate) position. Set GAIN control to the position which causes the Stylus to trace a line precisely 20 smallest chart divisions to the right of channel center. NOTE: 20 divisions are not equivalent to End Scale deflection, which is 25 divisions.

h) Return Function Switch to the OFF position and verify that the stylus is tracing a line at exactly channel center; correct if necessary by means of the Position control.

i) Repeat steps e) and f) until Stylus traces precisely at channel center in OFF and at +20 chart divisions in the CAL positions of the Function Switch.

j) The Signal may now be connected to the Signal Conditioner per Wiring Instructions given in Chapter II. The Position control and Function Switch may now be set at any position within their respective ranges of adjustment.

k) HOW TO USE ZERO SUPPRESSION:

i: Zero Suppression is a calibrated 10-times Full Scale Electrical position control at all settings of the Function Switch.* The purpose of 10 x Full Scale Zero Suppression is to allow expanded-scale recording of small A.C. signal components which are riding on top of a large D.C. component.

ii: First record the signal to be investigated without using Zero Suppression. And note the approximate peak-to-peak amplitude of the A.C. signal component as well as that of the D.C. component. To save chart paper, a calibrated oscilloscope may also be used for this purpose. If the Recorder itself is used for this purpose, best results will be attained by using a margin zero, that is, by initially setting the baseline of the trace at the left or right hand margin of its channel (depending upon whether the D.C. component is positive or negative, in that order.) Naturally, this initial setting should be made with the Function Switch in the OFF position.

iii: Refer to the Table below for suggested practical attenuator settings for various combinations of D.C. and A.C. components.

iv: If a positive D.C. component is to be suppressed, set the zero Suppress Switch to "+"; for a negative component, set the switch to "-".

v: Choose and record the type of "zero" (channel center or margin) which is to be used. Set this "zero" with the POS control with Function Switch in OFF position. DO NOT TOUCH POSITION CONTROL THEREAFTER, as all readings will be taken from this initial "zero".

*practical limit: 500 volts - See table below

1) i: ZERO SUPPRESSION TABLE

| FUNCTION SWITCH SETTING | MULTIPLIER (MV/div or V/div) | EFFECTIVE FULL-SCALE SENSITIVITY (MAX AC COMPONENT) | ZERO SUPPRESSION FOR ONE FULL TURN OF Z.S.DIAL | MAXIMUM ATTAINABLE ZERO SUPPRESSION (MAX DC COMPONENT) |
|---|---|---|---|---|
| 1 | mv/div | 50 mv(±25mv E.S.) | 50 mv | 500 mv |
| 2 | mv/div | 100 mv(±50mv E.S.) | 100 mv | 1 volt |
| 10 | mv/div | 500mv(±250mv E.S.) | 500 mv | 5 volts |
| 20 | mv/div | 1 volt(±500mv E.S.) | 1 volt | 10 volts |
| .1 | volt/div | 5 volts(±2.5v E.S.) | 5 volts | 50 volts |
| .2 | volt/div | 10 volts(±5v E.S.) | 10 volts | 100 volts |
| 1 | volt/div | 50 volts(±25v E.S.) | 50 volts | 450 volts MAXIMUM (4.5 TURNS) |
| 2 | volts/div | 100 volts (±50v E.S.) | 100 volts | 400 volts MAXIMUM (4.0 TURNS) |

ii: How to Use Zero Suppression Table

Examples:

35 mv P-P A.C. component riding on +750 mv D.C. level:

Function Switch: 2 mv/div position

Zero Suppress Switch: + position

Zero Suppress Dial: 7.50 turns (7.5 turns @100 mv/turn: 750mv)

Recorded Signal Amplitude: 17.5 chart divisions P-P

2.0 volt P-P A.C. component riding on -40 volt D.C. level:

Function Switch: 0.1 v/div position

Zero Suppress Switch: - position

Zero Suppress Dial: 8.0 turns (8.0 turns @5 v/turn: 40V)

Recorded Signal Amplitude: 20 chart divisions P-P

PRINCIPLES OF OPERATION

A. BASIC PRINCIPLES

1. PEN MOTOR: The Techni-Rite Pen Motor is a velocity feedback galvanometric device. It is highly efficient by virtue of the fact that it is fully shielded, and that its moving coil "sees" more than 90% of the magnetic field of the self-contained permanent magnet.

2. PEN MOTOR WITH SELF-CONTAINED INTEGRATED DRIVER AMPLIFIER A Techni-Rite exclusive. The Pen Motor-Amplifier combination is supplied as a sealed, complete unit requiring only D.C. power and a signal voltage to become a Recording System. The TR-888 Recorder is equipped with eight of these devices. Each Pen Motor-Amplifier accepts plus and minus power (regulated) ± 15 VDC at 325 Ma), a positioning voltage and a signal voltage, all as outputs from its associated Signal Conditioner. The basic sensitivity of the Pen Motor-Amplifier in the TR-888 is 8 millivolts per chart division. Internally, the Integrated Driver Amplifier supplies temperature and frequency compensated driving power to the Drive Coil of the Pen Motor, and accepts velocity signals (proportional to the rotational velocity of the Pen Motor shaft) from the Velocity Winding of the Pen Motor, to insure Input/Output phase relationship. A single control mounted on the top cap of the Amplifier/Pen Motor adjusts system damping over a wide range from underdamped to overdamped.

3. SIGNAL CONDITIONER: MODULES, GENERAL In the TR-888 Recorder, nearly all trouble-shooting and alignment may be done at the Signal Conditioner since it is the basic element in all Recording Channel functions. The Signal Conditioner accepts raw A.C. power from its (individual) power transformer located under the Chart Magazine, and produces smooth series-regulated D.C. power (±15.5v) which is used to operate the Signal Conditioner proper,

the calibration circuitry, and the Integrated Amplifier-Pen Motor. Because of this configuration, no special test fixtures are required to trouble-shoot a channel which is operating incorrectly. Only the extender card or cable TAC-130 is required.

4. SIGNAL CONDITIONER: MODULES, SPECIFIC A separate description of the specific functions of each module follows:

Signal Conditioner Module Model TSC-810:

References:

| | |
|---|---|
| Assembly Drawing | 401134 |
| Module Schematic | 401127 |
| P.C. Board Schematic | 401130 |

a) Physical Description

The TSC-810 Signal Conditioner has as its major structural components an extruded aluminum front panel on which the controls are mounted, and a heavy epoxy glass printed circuit board on which the electronic components are mounted. This "L" shaped assembly plugs directly into a printed circuit socket which is mounted against the base plate of the Recorder. The module is held in place by means of the friction of the P.C. socket against the board, and by means of two spring loaded friction pins located at the top and bottom of the front panel which plug into locating holes in the Recorder frame.

b) Electrical Description

The Module Signal input presents a constant 500K load to the signal throughout the nine available attenuator positions located on position 3 through 11 of the Function Switch. On the circuit board "side" of the Attenuator, the initially conditioned signal, referenced against Common, passes through protective resistor R7 to the protective input damping zener diodes CR2 and CR3, which effectively limit the maximum signal voltage seen by Input Pair Q1 to a safe value in case of a severe accidental

overload at the input of the Attenuator, in which case the excessive signal voltage would be dropped across R7.

Q1, the Input pair is connected in the now classical Darlington configuration so as to present a very high (30 to 50 megohms) load to the input attenuator, for the purpose of keeping attenuator loading to a minimum, and maintaining accurate attenuator ratios. Q1 is a single-chip pair, with excellent temperature characteristics. This portion of the circuit, consisting of Q1, R4, R6, R8, and R9 has a voltage gain of unity. The purpose of R9, the front-panel accessible Vo control, is to maintain a zero-input zero-output condition. R4 is a resistor selected to reduce the $I_o$ leakage out of the Base of the first transistor in Q1 to a level which will cause less than 0.2 divisions of stylus shift when switching the Function Switch through its range, (equivalent to 2mv at input). The $I_o$ is essentially a constant-current flow, and would otherwise produce a false "signal" at the input of Q1 equivalent to the $I_o$ current multiplied by the resistive value of the attenuator seen by Q1, which varies between 1K and 500K as the Function Switch is rotated through its range.

POWER SUPPLY:

The center-tapped secondary of a power transformer feeds a full-wave bridge rectifier module, CR6, whose output gives a positive and a negative voltage with respect to the transformer center tap (P.C. board common). This unfiltered D.C. output is smoothed by electrolytic capacitors C1 and C2 and then passes to the Series Regulators Q2 and Q3. Let us investigate the Positive Voltage Regulator section consisting of CR5, R11, and Q3:

These components are assembled into the simplest Series Regulator which is closely akin to an Emitter Follower whose Base

input voltage, and therefore Emitter output voltage is set and fixed by Zener Diode CR5. CR5 is supplied with current through dropping resistor R11 from the unregulated voltage supplying the Collector of Q3. CR5 is a 16 volt, 5% Zener, rated at one Watt. The net output voltage is 16 volts less 0.6 volt Emitter-to-Base drop in Q3, or 15.4 volts ±5%.

CALIBRATION CIRCUIT:

The calibration voltage circuit comprises R5, CR1, R1, R2, and R3. Reference Zener CR1, a 9 volt unit is connected to the regulated Positive Voltage supply through R5. This doubly regulated voltage, available at the junction of R1 and CR5 is fed to a voltage divider string consisting of R1, R3, and trimmer potentiometer R2. The output of R2, derived from its slider, is adjustable over a narrow range around 200 mv, the nominal calibration voltage. This calibration voltage signal is connected to position number 2 of the Function Switch.

STYLUS POSITION CONTROL CIRCUIT:

The Stylus position control potentiometer is connected between the +15.5 and -15.5V busses on the P.C. board and the slider of this control is connected directly to the Position input of the Integrated Amplifier Pen Motor.

GAIN CONTROL CIRCUIT:

The Gain Control potentiometer is connected between the output of Q1 and P.C. board Common. Since the sensitivity of the Integrated Amplifier Pen Motor is equal to approximately 8 millivolts per chart division, and since Q1 has a gain of one (1), the rated sensitivity of the system, 10 millivolts per chart division is attained when the slider is stationed at approximately 75% of its full scale (270°) rotation. The Control slider is connected directly to the Signal Input lead of the Integrated Amplifier Pen Motor.

MODEL TSC-801 Module, Reference Drawings 401133
401110
401064
600766

SPECIFIC: The Model TSC-801 Signal Conditioner Module has a D.C. gain of ten (10), and a balanced differential input. This yields a System sensitivity of 1 mv/div. The balanced Input Attenuator shows a constant impedance of 500K ohms to each input. The Input Attenuator occupies steps 4 through 11 of the Module Function Switch.

Note that the TSC-801 has inputs marked "+" and "-" on the schematic. A positive-going signal applied to the "+" input will cause the Recording stylus to give a positive indication (move to the right in the standard "Industrial" model Recorder). A positive-going signal applied to the "-" input will cause the Stylus to move to the left.

Circuit details are as follows:

Ref: 600766 & 401064

Signal Attenuator and Zero Suppress Circuit Details:

Function Switch S2 has two active decks, S2A and S2C; S2B is used for tie points. The selector of S2C directly feeds the non-inverting input and the selector of S2A feeds the inverting input of the module preamplifier section. Interposed between the selector of S2A and the preamplifier is R32 of the Zero Suppress circuit. R32 is a ten-turn precision potentiometer which is the adjustable element in the voltage divider circuit consisting of R31, R32, and R33. This voltage divider is supplied by 2.7 volt mercury Battery B1 through Polarity Reversal Switch S3. R33 is a resistor selected to bring the maximum available voltage across R32 to a level of 10 times the maximum ($\pm$25 (50) millivolt) signal from the Attenuator which can be recorded by the balance of the system or 500 millivolts. R32 in conjunction with B1 and S3 therefore allow a signal of up to 10X full-scale sensitivity of the System to be brought into the range of the system, at all attenuator positions of the Function Switch.

Input Protection Circuit:
Ref: 401064
R15, D1, and D2 constitute the input protection circuit for the non-inverting input of the Module preamplifier section. Silicon Signal diodes D1 are connected back-to-back across the + and - inputs of the Preamplifier and are back-biased at 1/2 of the negative supply, or approximately -7.5 volts, through the voltage divider consisting of R19 and R22. Diodes D2 and D3 are also connected across the + and - preamplifier inputs and are similarly biased at 1/2 of the positive supply, or +7.5 volts. Thus, any input voltage above approximately +8.0 volts will be shunted to Common, and excess signal level above 8.0 volts will be dropped across R15 and/or R16.

Input Matching Circuit & $I_o$ Adjustment:
Input Pair Q1 (two closely matched transistors etched onto a single "chip") form a pair of Emitter Followers which serve to present a very high input impedance to the "front end" (Attenuator & Input Protection circuit) of the Module. The collectors of Q1 are connected to the +15.5 VDC regulated supply and the Emitters are connected through their load resistors R10 and R11 to the -15.5 VDC regulated supply of the Module. The effective Input Impedance seen at both Bases of Q1 is equal to the value of R10 or R11 multiplied by the Current Gain of its associated transistor in Q1. Since the Current gain of Q1 lies in the range of 100 to 250, and R10 and R11 have a resistance of 500K ohms, the input impedance exhibited at the bases of Q1 will be between 50 and 125 megohms. The outputs of Q1 are limited in amplitude by the action of the input Protective Circuit D1 through D4, to approximately $\pm$ 8 volts referenced to Common. $I_o$ Adjustment potentiometer (accessible at Module front panel) is necessary to reduce the $I_o$ leakage currents from the Bases of Q1 to a minimum, or at least to the point where $I_o$ leakage is the same from each base. Otherwise, this

unbalanced current leakage from the bases would flow back into the Attenuator to Module Common, and would produce a "signal" (voltage difference) across the input Attenuator which would appear as a deflection of the Recorder Stylus, where no input signal is present. This would have an obviously bad effect upon the accuracy of recording. The net effect of $I_o$ control R23 and divider resistors R18 and R25 is to balance current flow into the Bases of Q1 through isolating resistors R14 and R24.

Voltage Gain Stage:
Integrated Operational Amplifier A1 is connected and operated in an "inverting" configuration. Its gain is set by the value of R8 (Rf) and R12 (Rs) by the ratio $Rf/_{Rs}$. In this case, Rf= 200K ohms, and Rs= 20K, yielding a DC gain of 10. Since the sensitivity of the Integrated Amplifier-Pen Motor is approximately 8 mv per chart division, the net maximum sensitivity of the Recorder channel is 0.8 mv per chart division.

R9 and R7 match R12 and R8 in value to present a balanced load to the outputs of Q1. R17, the front-panel $V_o$ trimmer, adjusts the Op-Amp for zero output with Zero Signal input. R6, C1 and C2 are used for the purpose of frequency compensation. R5 is necessary to prevent "latch-up" of the Op-Amp. The GAIN control potentiometer is connected between the output pin (6) of the Op-Amp and P.C. board common, with output taken from the slider of the GAIN control being fed directly to the Signal input of the Integrated Amplifier Pen Motor.

Position Control Voltage is derived from a potentiometer connected between the -15.5 and +15.5 VDC regulated supplies. The slider of the Position potentiometer is connected directly to the Position Signal input of the Integrated Amplifier Pen Motor.

Power Supply: The center-tapped secondary of a power transformer feeds full-wave rectifier bridge module CR4, whose

outputs yield a positive and a negative voltage with respect to the power transformer center tap (P.C. board Common buss.) These raw DC outputs are smoothed by electrolytic capacitors C3 and C4 and then pass to Series Regulators Q2 and Q3. Let us investigate the Positive Voltage Regulator consisting of CR3, R27, and Q3:

These components are assembled into the simplest Series Regulator, closely akin to an Emitter Follower whose Base voltage and therefore whose Emitter (output) voltage is fixed by Zener Diode CR3 at 16 volts, ±5%, Zener current is supplied through R27 from the unregulated supply, Zener CR3 is a 5% accurate device, and the resultant output voltage is 16 VDC less the 0.6 Base to Emitter drop in Q3, or 15.4 VDC ± 5% in the lightly loaded condition.

Calibration Circuit:
The calibration voltage Circuit comprises CR1, R1, R2 R3, and R4. Reference Zener CR1 is connected to the positive side of the regulated supply through R3. The double-regulated voltage available at CR1 is divided down to the 200 millivolt level in the divider string R1, R2 (10 turn trimmer) and R4. The voltage at the slider of R2 is adjustable over a narrow range around 200 millivolts, the nominal level. This voltage is divided at the Function Switch by a further factor of 10, and the resultant 20 millivolts is made available for calibration at position number 3 of the Function Switch.

5. BASIC RECORDER THEORY, ELECTRICAL
This section deals with the chart speed and stylus heat control circuitry.

a) Chart Speeds: The TR-888 Recorder is equipped with a two speed Hysterisis - Synchronous drive motor and a four-speed electrically selected transmission, for a total of 8 speeds from 0.5 to 10 millimeters per second. The various combinations of chart drive motor speeds and transmission

| Reading |
| --- |
| 0.5 |
| 1.0 |
| 1.5 |
| 5.0 |
| 10 |
| 25 |
| 50 |
| 100 |

ratios are selected by decks of the Chart Speeds switch, a S2 a,b,c,d, and are shown in the table below:
Ref: Schematic No. 600768

| CHART SPEED mm/sec. | DRIVE MOTOR RPM | TRANSMISSION RATIOS ENGAGED |
|---|---|---|
| 0.5 | 900 | 5:1 & 20:1 |
| 1.0 | 1800 | 5:1 & 20:1 |
| 2.5 | 900 | 20:1 |
| 5.0 | 1800 | 20:1 |
| 10 | 900 | 5:1 |
| 20 | 1800 | 5:1 |
| 50 | 900 | NONE |
| 100 | 1800 | NONE |

Note on Schematic 600768 that Drive Motor speed switching is accomplished through Relay K1. This is done in order to remove the heavy inductive load of the Drive Motor from the Chart Speeds switch and to help prevent radiation of the inductive motor switching surge within and without the Recorder, by means of keeping the motor power leads short. With respect to the Transmission, the A.C. voltage fed to the speed-change clutch actuator coils is rectified by bridge Rectifiers which are an integral sealed component of the Transmission. In addition, each coil has across it a backward connected single diode which conducts only when a sudden disconnection of power (speed change) produces a sudden surge of reverse voltage. This prevents the reverse EMF surge from becoming a "pip" on all Recorder Channels, and from interfering with the operation of other equipments operating in the vicinity.

6. STYLUS HEAT CONTROL:

The one remaining deck of the CHART SPEEDS control S2e, switches the primary taps of transformer T9 in such a manner that an increasing Stylus Power voltage appears at the 9 separate second-

ary windings of the transformer with each increase in Chart Speed above 2.5 mm/sec. Thus, the trace on the chart will remain reasonably constant for all chart speeds. In addition, a separate potentiometer Control is included for each Stylus to give an additional 10:1 Stylus power adjustment to adjust each Stylus according to the particular characteristics of the signal which it is recording.

7. POLICY REGARDING DOCUMENTATION OF "SPECIALS"

Formalized information regarding specialized Recorders will be in the form of Addenda Sheets at the front of this Manual, with a brief listing of special components used if in our opinion they will affect spare parts provisioning. No additional Theory of Operation information or pictorial parts listing will be given except against an extra payment. In the case of short-run (low quantity) specials, we reserve the right to supply only hand-marked non-reproducible copies of the schematic or schematics involved, or to mark up the Schematic (s) and Parts Lists contained in this Manual.